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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Present Application:

Applicants : ROUNDHILL, David N. et al.
Attorney Docket No.: 500789.01
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Title : ULTRASOUND HARMONIC IMAGING SYSTEM AND METHOD

Prior Application:

Examiner : F. Jaworski
Art Unit : 3737
Serial No. : 08/943,546

PRELIMINARY AMENDMENT

Box Patent Application
Assistant Commissioner of Patents
Washington, D.C. 20231

Sir:

Please amend the above-identified application as follows:

In the Title:

Please amend the title to read as follows: --SYSTEM AND METHOD FOR THREE DIMENSIONAL HARMONIC ULTRASOUND IMAGING--

In the Specification:

Page 1, line 4, change "This is" to -- This application is a divisional application of pending U.S. patent application serial number No. 09/247,343, filed February 8, 1999, and entitled "ULTRASONIC DIAGNOSTIC IMAGING SYSTEM WITH BLENDED TISSUE HARMONIC SIGNALS" which is --

In the Claims:

Please delete claim 1-27, and add new claims 28-106 as follows:

28. An ultrasonic imaging system for producing a 3 dimensional image of ultrasound reflectors inside a body, comprising:

an ultrasound transducer;

an ultrasound transmitter coupled to the ultrasound transducer, the ultrasound transducer being operable to generate a signal having a fundamental frequency;

an ultrasound receiver coupled to the ultrasound transducer, the ultrasound receiver being operable to receive a signal from the ultrasound transducer corresponding to ultrasound reflections from ultrasound reflectors at a plurality of depths in the body;

a filter coupled to the ultrasound receiver, the filter being operable to selectively pass signals received by the receiver having a frequency that is a harmonic of the fundamental frequency and to provide an output signal corresponding thereto; and

an image processor coupled to receive the output signal from the filter, the image processor being operable to generate a 3 dimensional image from the output signal of the filter.

29. The ultrasonic imaging system of claim 28 wherein the filter is further operable to pass signals at the fundamental frequency so that the output signal is a combination of signals received by the receiver having the fundamental frequency and signals received by the receiver having the harmonic frequency.

30. The ultrasonic imaging system of claim 29 wherein the filter further comprises:

a low frequency channel operable to pass components of the signals received by the receiver having the fundamental frequency;

a high frequency channel operable to pass components of the signals received by the receiver having the harmonic frequency; and

a combiner operable to combine the signals passed through the low frequency channel and the signals passed through the high frequency channel.

31. The ultrasonic imaging system of claim 30 wherein the low frequency channel is further operable to attenuate signals reflected from ultrasound reflectors at

shallower depths of the body to a greater extent than signals reflected from ultrasound reflectors at greater depths of the body, and the high frequency channel is further operable to attenuate signals reflected from ultrasound reflectors at greater depths of the body to a greater extent than signals reflected from ultrasound reflectors at shallower depths of the body so that deeper portions of the 3-dimensional image are produced predominantly from signals received by the receiver having the fundamental frequency and shallower portions of the 3-dimensional image are produced predominantly from signals received by the receiver having the harmonic frequency.

32. The ultrasonic imaging system of claim 31 wherein the high frequency channel includes a depth-dependent time varying filter to attenuate signals passing through the channel as a function of depth of the body.

33. The ultrasonic imaging system of claim 28 wherein the ultrasound reflectors comprise tissue or fluid, and wherein the three dimensional image is generated in the absence of an ultrasound contrast agent.

34. The ultrasound imaging system of claim 30 wherein the combiner comprises a switch operable to alternatively couple either the low frequency channel or the high frequency channel to the image processor.

35. The ultrasound imaging system of claim 30 wherein the combiner comprises a summing device operable to generate a composite signal formed from both a fundamental frequency signal coupled through the low frequency channel and a harmonic frequency signal coupled through the high frequency channel.

36. The ultrasound imaging system of claim 28 further comprising a Doppler processor coupling the image processor to the filter, the Doppler processor being operable to generate a Doppler signal from the output signal of the filter, the Doppler signal being applied to the image processor so that the 3 dimensional image corresponds to ultrasound reflections from moving ultrasound reflectors.

37. The ultrasound imaging system of claim 36 wherein the Doppler signal is indicative of the velocity of the moving ultrasound reflectors.

38. The ultrasound imaging system of claim 36 wherein the Doppler signal is indicative of the intensity of reflections from the moving ultrasound reflectors

39. The ultrasound imaging system of claim 28 wherein the filter is further operable to shift the frequency of the signals received by the receiver having the harmonic to a different frequency.

40. The ultrasound imaging system of claim 28 wherein the filter comprises a finite impulse response filter operable to filter and decimate the signals received by the receiver.

41. The ultrasound imaging system of claim 28 wherein the transmitter is operable to generate first and second successive pulses of signals at the fundamental frequency having different phases, and wherein the filter comprises a signal processor operable to combine a first signal received from the receiver resulting from the first successive pulse with a second signal received from the receiver resulting from the second successive pulse.

42. The ultrasound imaging system of claim 28 wherein the signal generated by the ultrasound transmitter has a range of frequency components, the range of frequency components including the fundamental frequency.

43. An ultrasonic imaging system for producing a 3 dimensional image of ultrasound reflectors inside a body, comprising:

an ultrasonic transducer operable to transmit ultrasonic pulses into a body and receive echo signals responsive to the pulses, the ultrasonic pulses having a fundamental frequency component;

a beamformer coupled to receive the echo signals from the ultrasonic transducer and to generate output signals corresponding thereto;

a filter coupled to receive the output signals from the beamformer, the filter being operable to selectively pass harmonic frequency components of the beamformer output signals that are a harmonic of the fundamental frequency component; and

an image processor coupled to the filter to receive the harmonic frequency components of the beamformer output signals, the image processor being operable to generate a 3 dimensional image from the harmonic frequency components of the beamformer output signals.

44. The ultrasonic imaging system of claim 43 wherein the filter comprises a digital filter.

45. The ultrasonic imaging system of claim 43 wherein the filter is further operable to pass fundamental frequency components of the beamformer output signals so that the image is formed from fundamental and harmonic frequency components of the beamformer output signals.

46. The ultrasonic imaging system of claim 45 wherein the filter comprises:

a low frequency channel operable to pass the fundamental frequency components;

a high frequency channel operable to pass the harmonic frequency components; and

a combiner operable to combine the fundamental frequency components with the harmonic frequency components.

47. The ultrasonic imaging system of claim 46 wherein the low frequency channel is further operable to attenuate signals reflected from ultrasound reflectors at shallower depths of the body to a greater extent than signals reflected from ultrasound reflectors at greater depths of the body, and the high frequency channel is further operable to attenuate signals reflected from ultrasound reflectors at greater depths of the body to a greater extent than signals reflected from ultrasound reflectors at shallower depths of the body so that deeper portions of the 3-dimensional image are produced predominantly from the fundamental frequency components and shallower portions of the 3-dimensional image are produced predominantly from the harmonic frequency components.

48. The ultrasonic imaging system of claim 46 wherein the high frequency channel each includes a depth-dependent time varying filter to attenuate signals passing through the channel as a function of the depth from which the echo signals are received.

49. The ultrasonic imaging system of claim 46 wherein the low frequency channel is operable to attenuate signals reflected from ultrasound reflectors at a first range of depths to a greater extent than signals reflected from ultrasound reflectors at a second range of depths, and to attenuate signals reflected from ultrasound reflectors at the second range of depths to a greater extent than signals reflected from ultrasound reflectors at a third range of depths, and wherein the high frequency channel is operable to attenuate signals reflected from ultrasound reflectors at the third range of depths to a greater extent than signals reflected from ultrasound reflectors at the second range of depths, and to attenuate signals reflected from ultrasound reflectors at the second range of depths to a greater extent than signals reflected from ultrasound reflectors at the first range of depths, the third range of depths being deeper than the second range of depths, and the second range of depths being deeper than the first range of depths so that portions of the 3-dimensional image in the third range of depths are produced predominantly from the fundamental frequency component, portions of the 3-dimensional image in the first range of depths of the body are produced predominantly from the harmonic frequency component, and portions of the 3-dimensional image in the second range of depths are produced substantially equally from the fundamental frequency component and the harmonic frequency component.

50. The ultrasonic imaging system of claim 46 wherein the combiner comprises a switch operable to alternatively couple either the low frequency channel or the high frequency channel to the image processor.

51. The ultrasonic imaging system of claim 46 wherein the combiner comprises a summing device operable to generate a composite signal formed from both the fundamental frequency component coupled through the low frequency channel and the harmonic frequency component coupled through the high frequency channel.

52. The ultrasonic imaging system of claim 43 further comprising a Doppler processor coupling the image processor to the filter, the Doppler processor being operable to generate a Doppler signal from the harmonic frequency component, the Doppler

signal being applied to the image processor so that the 3 dimensional image corresponds to ultrasound reflections from moving ultrasound reflectors.

53. The ultrasonic imaging system of claim 52 wherein the Doppler signal is indicative of the velocity of the moving ultrasonic reflectors.

54. The ultrasonic imaging system of claim 52 wherein the Doppler signal is indicative of the intensity of reflections from the moving ultrasonic reflectors

55. The ultrasonic imaging system of claim 43 wherein the filter is further operable to shift the frequency of the harmonic frequency component.

56. The ultrasonic imaging system of claim 43 wherein the filter comprises a finite impulse response filter operable to filter and decimate the beamformer output signals.

57. The ultrasonic imaging system of claim 43 wherein the ultrasonic pulses comprise first and second successive pulses of signals having the fundamental frequency component, the first and second pulses having different phases, and wherein the filter comprises a signal processor operable to combine a first output signal from the beamformer derived from an echo signal responsive to the first successive pulse with a second signal from the beamformer derived from an echo signal responsive to the second successive pulse.

58. The ultrasonic imaging system of claim 43 wherein each of the ultrasonic pulses transmitted into the body have a range of frequency components, the range of frequency components including the fundamental frequency component.

59. A display device displaying a 3-dimensional image of an interior of a body, the 3-dimensional image being formed from harmonic frequency echo signals generated by interaction of fundamental frequency ultrasound signals with ultrasound reflectors within the body.

60. The display device of claim 59 wherein the 3-dimensional image is further formed from fundamental frequency echo signals generated by the reflections of the

fundamental frequency ultrasound signals so that the 3-dimensional image is formed from a combination of the harmonic frequency echo signals and the fundamental frequency echo signals.

61. The display device of claim 60 wherein the harmonic frequency echo signals and the fundamental frequency echo signals are alternately used to form the 3-dimensional image at different times.

62. The display device of claim 60 wherein the harmonic frequency echo signals and the fundamental frequency echo signals are simultaneously used to form the 3-dimensional image.

63. The display device of claim 60 wherein a first portion of the 3-dimensional image is primarily formed using the fundamental frequency echo signals, and a second portion of the 3-dimensional image is primarily formed using the harmonic frequency echo signals, the first portion of the 3-dimensional image being deeper within the body than the second portion of the 3-dimensional image.

64. The display device of claim 59 wherein the ultrasound comprise tissue or fluid and wherein the reflections are produced in the absence of an ultrasound contrast agent.

65. The display device of claim 59 wherein the 3-dimensional image is formed from harmonic frequency echo signals generated by an interaction of fundamental frequency ultrasound signals with moving ultrasound reflectors within the body and tissue within the body.

66. The display device of claim 65 wherein the 3-dimensional image is formed from harmonic frequency echo signals indicative of the velocity of the moving ultrasound reflectors.

67. The display device of claim 65 wherein the 3-dimensional image is formed from harmonic frequency echo signals indicative of the intensity of reflections from the moving ultrasound reflectors

68. The display device of claim 59 wherein the 3-dimensional image is formed from harmonic frequency echo signals generated by interactions of fundamental frequency ultrasound signals with contrast agents within the body.

69. The display device of claim 59 wherein the 3-dimensional image is formed from harmonic frequency echo signals generated by interactions of fundamental frequency ultrasound signals solely with tissues within the body.

70. The display device of claim 59 wherein the fundamental frequency ultrasound signals have a range of frequency components, the range of frequency components including the fundamental frequency.

70. A method of generating a 3-dimensional image of ultrasound reflectors inside a body, comprising:

transmitting an ultrasound signal into the body, the ultrasound signal having at least a fundamental frequency;

detecting echoes of the transmitted ultrasound signal at a harmonic frequency that is a multiple of the fundamental frequency; and

using the detected echoes to form a 3-dimensional image.

71. The method of claim 70, further comprising, prior to transmitting the ultrasound signal, introducing a contrast agent into the body.

72. The method of claim 70, further comprising:

detecting echoes of the transmitted ultrasound signal at the fundamental frequency; and

using the detected echoes at both the fundamental frequency and the harmonic frequency to form the 3-dimensional image.

73. The method of claim 72 wherein the detected echoes at the fundamental frequency are used to form the 3-dimensional image alternately with the use of the detected echoes at the harmonic frequency to form the 3-dimensional image.

74. The method of claim 72 wherein the detected echoes at the fundamental frequency and the detected echoes at the harmonic frequency are used simultaneously to form the 3-dimensional image.

75. The method of claim 72 wherein the detected echoes at the fundamental frequency are used to form portions of the 3-dimensional image that are at a greater depth within the body, and the detected echoes at the harmonic frequency are used to form portions of the 3-dimensional image that are at a shallower depth within the body.

76. The method of claim 72 wherein the detected echoes at the fundamental frequency are used to form portions of the 3-dimensional image that are at a greater depth within the body, the detected echoes at the harmonic frequency are used to form portions of the 3-dimensional image that are at a shallower depth within the body, and both the detected echoes at the fundamental frequency and the detected echoes at the harmonic frequency are used to form portions of the 3-dimensional image that are at an intermediate depth within the body.

77. The method of claim 70 wherein the act of detecting echoes of the transmitted ultrasound signal comprises detecting echoes from moving ultrasound reflectors within the body.

78. The method of claim 77 wherein the act of using the detected echoes to form a 3-dimensional image comprise displaying the 3-dimensional image with indicia indicative of the velocity of the moving ultrasound reflectors.

79. The method of claim 77 wherein the act of using the detected echoes to form a 3-dimensional image comprise displaying the 3-dimensional image with indicia indicative of the intensity of the echoes reflected from the moving ultrasound reflectors.

80. The method of claim 70 wherein the act of transmitting an ultrasound signal into the body comprises transmitting an ultrasound signal into the body having a range of frequency components, the range of frequency components including the fundamental frequency.

81. A method of producing a 3-dimensional ultrasonic image, comprising:

transmitting ultrasonic signals into the body, the transmitted ultrasonic signals having a fundamental frequency component;

receiving ultrasonic echoes from ultrasonic reflectors within the body, the received ultrasonic echoes including a frequency component that is a harmonic of the fundamental frequency component;

storing signals derived from the harmonic frequency component of the received ultrasonic echoes; and

displaying a 3-dimensional image from the stored signals.

82. The method of claim 81, further comprising, prior to transmitting the ultrasonic signals, introducing a contrast agent into the body.

83. The method of claim 81 wherein the act of receiving echoes from ultrasonic reflectors within the body comprises receiving echoes from moving ultrasonic reflectors within the body.

84. The method of claim 83 wherein the act of receiving echoes from moving ultrasonic reflectors within the body comprises receiving echoes from moving ultrasonic reflectors within the body.

85. The method of claim 83 wherein the act of displaying a 3-dimensional image from the stored signals comprises displaying a 3-dimensional image from the stored signals containing information indicative of the velocity of the moving ultrasonic reflectors.

86. The method of claim 83 wherein the act of displaying a 3-dimensional image from the stored signals comprises displaying a 3-dimensional image from the stored signals containing information indicative of the intensity of the echoes reflected from the moving ultrasonic reflectors.

87. The method of claim 81 wherein the act of transmitting ultrasonic signals into the body comprises transmitting ultrasonic signals having a range of frequency components, the range of frequency components including the fundamental frequency component.

88. A method of producing a 3-dimensional ultrasonic image, comprising:

transmitting ultrasonic signals into the body, the transmitted ultrasonic signals having a fundamental frequency component;

receiving ultrasonic echoes from ultrasonic reflectors within the body, the received ultrasonic echoes containing both fundamental and harmonic frequency components;

detecting the fundamental and harmonic frequency components of the ultrasonic echoes;

forming signals that are a blend of the detected fundamental and harmonic frequency components;

storing the formed signals; and

displaying a 3-dimensional image from the stored signals.

89. The method of claim 88, wherein the blend of fundamental and harmonic frequency components varies as a function of time.

90. The method of claim 88, wherein the blend of fundamental and harmonic frequency components varies as a function of the depth of the ultrasonic reflectors.

91. The method of claim 88, wherein the blend of fundamental and harmonic frequency components varies as a function of the location of the ultrasonic reflectors

92. The method of claim 88, further comprising, prior to transmitting the ultrasonic signals, introducing a contrast agent into the body.

93. The method of claim 88, wherein the ultrasonic reflectors comprise a contrast agent.

94. The method of claim 88 wherein the act of receiving echoes from ultrasonic reflectors within the body comprises receiving echoes from moving ultrasonic reflectors within the body.

95. The method of claim 94 wherein the act of displaying a 3-dimensional image from the stored signals comprises displaying a 3-dimensional image from the stored signals containing information indicative of the velocity of the moving ultrasonic reflectors.

96. The method of claim 94 wherein the act of displaying a 3-dimensional image from the stored signals comprises displaying a 3-dimensional image from the stored signals containing information indicative of the intensity of the echoes reflected from the moving ultrasonic reflectors.

97. The method of claim 88 wherein the act of transmitting ultrasonic signals into the body comprises transmitting ultrasonic signals having a range of frequency components, the range of frequency components including the fundamental frequency component.

98. The method of claim 88 wherein the detected fundamental frequency component and the detected harmonic frequency component are alternately used to form the 3-dimensional image.

99. The method of claim 88 wherein the detected fundamental frequency component and the detected harmonic frequency component are simultaneously used to form the 3-dimensional image.

100. The method of claim 88 wherein the detected fundamental frequency component is used to form portions of the 3-dimensional image that are at a greater depth within the body, and the detected harmonic frequency component is used to form portions of the 3-dimensional image that are at a shallower depth within the body.

101. The method of claim 88 wherein the detected fundamental frequency component is used to form portions of the 3-dimensional image that are at a greater depth within the body, the detected harmonic frequency component is used to form portions of the 3-dimensional image that are at a shallower depth within the body, and both the detected fundamental frequency component and the detected harmonic frequency component are used to form portions of the 3-dimensional image that are at an intermediate depth within the body.

102. A method for producing a three dimensional reconstruction with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy at a first frequency band into a subject during said imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) filtering from said echo information a plurality of information signals associated with a second frequency band, said second frequency band comprising at least a harmonic band of said first frequency band; and

(d) forming the three-dimensional reconstruction in response to said information signals.

103. An ultrasound apparatus adapted for generating a three dimensional reconstruction of a subject during an imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session, said apparatus comprising:

a transducer;

a transmit beamformer operatively connected to said transducer for transmitting ultrasonic energy into a subject during said imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session;

a receive beamformer operatively connected to said transducer and configured to obtain echo information;

a filter operatively connected to said receive beamformer and operative to filter from said echo information a plurality of information signals associated with a harmonic frequency band, said harmonic frequency band comprising harmonics of a fundamental frequency band transmitted into the subject; and

wherein the three-dimensional reconstruction is responsive to said information signals.

104. A method for producing a three dimensional reconstruction with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy at a first frequency band into a subject during said imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a plurality of detected Doppler information signals associated with a second frequency band, said second frequency band comprising at least a harmonic band of said first frequency band;

(d) forming the three-dimensional reconstruction in response to said information signals; and

(e) displaying a Doppler image selected from the group of: velocity, variance, energy and combinations thereof, the Doppler image being responsive to said three dimensional reconstruction.

105. A method for producing a three dimensional reconstruction with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy at a first frequency band into a subject during said imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session, said ultrasonic energy characterized by a peak power level near said first frequency band;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a plurality of information signals associated with a second frequency band, said second frequency band comprising at least a harmonic band of said first frequency band, and a second plurality of information signals associated with said first frequency band;

(d) forming the three-dimensional reconstruction in response to said information signals; and

(e) displaying a composite image responsive to said three dimensional reconstruction and representing three dimensions, said composite image comprising spatially distinct near-field and far-field regions, said far-field region emphasizing information signals in the first frequency band and said near-field region emphasizing information signals in the second frequency band.

106. A method for producing a three dimensional reconstruction with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy at a first frequency band into a subject during said imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a first plurality of information signals associated with said first frequency band and a second plurality of information signals associated with a second frequency band, said second frequency band comprising at least a harmonic band of said first frequency band;

(d) compounding the first and second plurality of information signals; and

(e) forming the three-dimensional reconstruction as a function of said compounded information signals.

REMARKS

Claims 28-101 have been presented to claim forming 3-dimensional images using harmonic ultrasound imaging from contrasts agents and tissue. Claims 102-106 are being presented to provoke an interference with U.S. Patent No. 5,928,151, which issued on July 27, 1999.

Respectfully submitted,

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